32

Raisin Harvest Mechanization: A Bit of History

HENRY E. STUDER

In 1953, A. J. Winkler of the Department of Viticulture and Enology at UC Davis initiated the first organized effort to machine-harvest grapes. His pioneering work led to the inverted L trellis and the cutter-type harvester, which was designed and tested in 1954 by a team of engineers from the Department of Agricultural Engineering led by Lloyd Lamouria. The harvester was designed to cut the fruit clusters from cane- or spur-pruned vines trained so that the shoots and clusters were supported by a set of horizontal wires. The harvester, attached to the side of a tractor, consisted of a cutting device held against the underside of the trellis wires. The stems of clusters hanging below the wires were severed by the cutter. Fruit to be used as wine grapes was delivered by conveyor to a gondola; fruit to be dried as raisins was discharged onto a continuous paper tray laid down by the harvester.

THE CUTTERBAR HARVESTER

The harvesting machine was commonly known as the *cutterbar harvester,* so named for the unguarded double-sickle cutter used to sever the stems. The harvester's efficiency at detaching the fruit depended on the position of the clusters hanging beneath the trellis wires. In order to achieve the proper position for machine harvest, the shoots had to be positioned by hand and the clusters manipulated by hand in late spring and early summer, respectively. The harvest efficiency was also a function of the cluster stem length and therefore of grape variety. Harvest trials were conducted beginning in 1955, and the machine was improved each year through 1963. A towed machine (Figure 32.1) with an operator seated behind the cutter and beneath the trellis was first tested in 1961. Over the years, several grape varieties were tested, including 'Thompson Seedless,' 'Malaga,' and 'Black Monukka' in plots at Davis, Madera, Fresno, Delano, and Arvin. Under the best of experimental conditions, more than 90 percent of the fruit was recovered from the vines. Under conditions more typical of commercial operations, efficiency with 'Thompson Seedless' and some other varieties was reduced to 80 percent or less.

Figure 32.1 UC Davis cutterbar harvester for raisin grapes. *Photo: L. Lamouria.*

Cutterbar harvesting of raisin grapes offered several significant advantages over hand harvesting. The labor requirement during the peak harvest period in September was drastically reduced since the machine operated at rates of an acre per hour with a crew of only three. While the technique required shoot positioning and cluster manipulation labor, these operations took place well before the harvest season. The harvester delivered the fruit mostly as intact clusters, very much like hand harvesting, though many machine-harvested clusters were cut through. The continuous tray offered the possibility that fruit turning and raisin pickup operations could be fully mechanized, and tests were carried out with the Stanley Raisin Maker in this regard.

The proposed system also had serious disadvantages. Special trellising was required, along with vine retraining. The inverted L trellis tended to be unstable. A 5-foot-wide T trellis that was subsequently proposed and tested required that vineyards be replanted with a wider row spacing to allow the fruit to sun-dry between the rows. Performance was very much dependent upon grape variety, and the system's efficiency with the most important raisin variety, 'Thompson Seedless,' was only borderline. A breeding program to develop longer-stemmed varieties seemed necessary to provide a long-term solution to this problem. In addition, trellising was more capital intensive, and trellis maintenance and pruning costs were higher. Finally, the harvest method did not substantially reduce overall labor requirements or production costs. Labor requirements were simply spread over a longer time period.

SHAKE HARVESTING OF JUICE GRAPES

The cutterbar harvester fired the imaginations of other researchers interested in grape harvest mechanization, and development work continued on this principle in Europe even into the 1970s. Meanwhile, researchers in New York State were attempting to harvest 'Concord' juice grapes using vibration. These early experiments commenced in 1957 and led to the development of the Geneva Double Curtain (GDC) trellis by Nelson Shaulis at the New York State Agricultural Experiment Station in Geneva, New York, and to the concept of shaking an offset cordon support wire vertically to detach the fruit as single berries. The harvester, developed by E. Stanley Shepardson in the Cornell University Department of Agricultural Engineering, delivered a low amplitude, high frequency bumping to the underside of the trellis-supported cordon as it moved along the row. An automatic guidance system allowed the shaker to accommodate the substantial sag in the cordon wire between the trellis supports, which were spaced at 24-foot intervals along the row.

RAISIN GRAPE HARVEST BY VERTICAL IMPACT TO THE TRELLIS WIRE

Experiments conducted at UC Davis in 1964 showed that a high impact applied to the underside of a fruiting cane support wire would snap the stems of large-clustered, weak-stemmed varieties such as 'Thompson Seedless.' This idea led to the development of the Duplex vine training system by Harold Olmo of the Department of Viticulture and Enology. The training system divided the vine into two regions: a vegetative region near the vine head for production of replacement fruiting canes, and a fruit-bearing zone located on offset fruiting cane support wires. The manual removal of flowers in the vine head region in the spring confined fruit production to the support wires. A tractor-mounted machine designed to deliver periodic blows to the underside of the trellis wires was tested in 1965, and a hypocycloidal impacter mechanism was developed and tested in 1966. The device produced high impact even under high wire-sag conditions, and was very effective in detaching 'Thompson Seedless' fruit as whole clusters or cluster fragments. However, the impacter harvester was soon rendered obsolete by two other developments: the rod shaker and cane severing.

THE ROD-TYPE SHAKE HARVESTER

In 1967, the Chisholm-Ryder Company tested the prototype commercial grape harvester shown in Figure 32.2, which shook the vine from side to side with banks of flexible paddles (these were subsequently replaced with fiberglass-reinforced rods). The machine's design was based on that of a harvester built and tested by J. R. Orton, a 'Concord' grape grower in Ripley, New York. This type of machine for the first time offered the possibility that grapes produced on conventionally trellised and trained vines (cane pruned or spur pruned) could be mechanically harvested. The harvest principle worked with most varieties, although the early machines produced a goodly amount of juice from some. Machine harvest of 'Thompson Seedless'

Figure 32.2 Early Chisholm-Ryder Co. grape harvester with flat paddles. *Photo: Henry E. Studer.*

for winemaking suddenly seemed a possibility for many growers.

CANE SEVERING: A CLASSIC EXAMPLE OF SERENDIPITY

In 1965, while conducting the impact harvesting studies at the UC Kearney Agricultural Center in Parlier, researchers severed the fruiting canes on several 'Thompson Seedless' vines near the vine heads in order to allow the harvester unconstrained manipulation of the cane support wire. Several of these canes remained unharvested at the end of the week (Figure 32.3), and when the work continued the following week, researchers discovered that even a moderate, manually applied shake would completely dislodge the fruit from these severed canes. Moreover, most of the fruit detached as single berries with the capstems (pedicels) still attached, as shown in Figure 32.4. The harvested fruit appeared to be very dry and exhibited only minor damage. Subsequent tests of other grape varieties showed that 'Thompson Seedless' was truly unique in its response to cane severing. The capstems of this variety dry rapidly and become very brittle within a few days, long before any berry shrivel can be observed. No other variety has been found to exhibit this characteristic to the same extent.

SHAKE-HARVESTING 'THOMPSON SEEDLESS' FROM SEVERED CANES

The shake harvesting of 'Thompson Seedless' vines could begin about 4 days after cane severing (the exact waiting period depends on temperatures after the canes are cut). Vertical-impact shaking of these cane-severed vines offered no advantage over rod shaking. In fact, rod shaking proved a decided advantage since whole-cluster detachment was minimized, and even the fruit borne on spurs in the head of the vine detached as single berries (albeit with more damage to those berries). Metering and spreading single berries onto a continuous tray was much easier than for whole or partial clusters. The single berries dried more quickly, and tray turning and rolling were unnecessary. The dried fruit could be retrieved from the tray mechanically, and equipment was developed to perform this operation (Figure 32.5). The fruit on severed canes stored well on the vine, did not shatter to the ground, and dried out quickly after a rain. A three-person crew could harvest at a rate of about 1 acre per hour and they could pick the raisins up at approximately the same rate.

Cane severing does reduce fruit production in following years. By paying careful attention to where you cut the canes, you can minimize the negative effects of cane severing. It remains to be shown that these effects can be eliminated completely, even with special trellising. When crews use power shears, cane severing for 1 acre requires 4 to 5 hours of labor. Severing the canes is more labor intensive than the machine harvesting operation itself. Continuous paper tray costs are higher for machine harvesting than for hand harvesting

Figure 32.3 'Thompson Seedless' fruiting canes, seven days after cane severing, with the fruit clusters still attached.
Photo: Henry E. Studer.

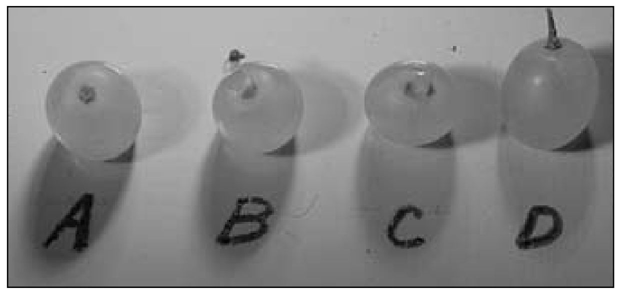

Figure 32.4 Moderate shaking detaches 'Thompson Seedless' grapes as single berries, most being undamaged, with or without capstem, as in *A* or *D*. *Photo: Henry E. Studer.*

Figure 32.5 The pickup machine tensions the paper tray and sweeps the raisins off as the machine moves along the row.
Photo: Henry E. Studer.

since the fruit load per unit of tray area is less than for hand-harvested fruit, and machine harvesting requires a heavier basis-weight paper (preferably extensible Kraft, which is less likely to rip when the paper shrinks during field drying).

Single berries on the tray are vulnerable to rain damage, especially fermentation. However, given good drying weather, the overall drying time is less than 14 days. This short drying time reduces the probability of rain damage, but if rain does occur early in the drying period the fruit is very vulnerable. The rod shaker will deliver most of the fruit to the tray as single berries whether the canes are cut or not, but the incidence and extent of berry damage are much higher if the canes are not cut. While tests have shown that this damaged fruit can usually meet USDA incoming inspection standards for mechanical damage, the damaged berries are more likely to stick to the continuous paper tray. Retrieval of the dried fruit from the tray is more difficult and less efficient under these conditions. You can reduce the probability of rain damage by cutting canes on all vines at the beginning of the harvest since fruit on severed canes does not deteriorate after a rain. However, this advantage may be offset by a reduction in quality and yield due to reduced sugar accumulation.

During the drying process, the capstem of the berry and the cluster rachis gain moisture during the night, especially if the temperature reaches dew point. Until they dry again, they lose their brittle character, fail to break when shaken, and the berries separate from the cluster without their capstems and with more skin breaks. Depending on atmospheric conditions, ideal harvesting conditions may be confined to the period from 11 AM to 8 PM. This represents a potential harvest rate of about 9 acres per day for each machine, or, optimistically, a production of 180 acres per season for each machine. Thus, the capital cost per acre of a grape harvester is higher for raisin harvest onto continuous trays than for wine grape harvest. Earl Rocca, a raisin grower near Biola, California, has experimented with this raisin production system for many years. He has developed special equipment and management techniques for vine training, cane severing, harvesting, spreading (Figure 32.6), picking up, and handling the machine-harvested fruit. He remains the only grower to adopt this system completely and to use it consistently and successfully year after year.

Figure 32.6 An apparatus built by raisin grower Earl Rocca for spreading machine-harvested single berries onto a continuous paper tray. *Photo: Henry E. Studer.*

CANE SEVERING AND DOV RAISINS

Efforts to produce dried-on-the-vine (DOV) raisins from 'Thompson Seedless' grapes commenced in 1965 and continued in 1969 and 1970 at the Kearney Agricultural Center. The fruiting canes were wrapped on two wires supported on a 5-foot crossarm. The fruiting canes were cut at fruit maturity (around September 1) and the fruit was allowed to dry for several weeks while hanging from the trellis wires (Figure 32.7). Drying was highly variable depending on the location of the clusters on the vine (north or south exposure) and the position of the berries in the cluster. Shaded berries remained green even into November (Figure 32.8). South-exposed berries dried to about 20 percent moisture in 6 weeks. Green berries at 60 percent moisture could be found even after 6 weeks. Green and black molds became increasingly obvious as the drying period extended into November, and clusters infested with European driedfruit beetle were common. The study showed that 'Thompson Seedless' grapes could be dried on the vine to 25 to 35 percent moisture after 6 weeks, depending on fruit orientation and exposure to the sun. The raisins did not dry to an acceptable average moisture content on the vine; drying was completed in a dehydrator with acceptable color development. The results suggested that drying on the vine, if supplemented by time in a dehydrator, might serve as a substitute for sun drying on trays.

'Zante Currant' raisins can be produced by drying 'Black Corinth' grapes on severed canes. In most years, this early maturing grape will dry to an acceptable moisture content within 5 to 6 weeks, and can then be shake-harvested directly into bins (Figure 32.9). The DOV 'Zante Currant' is finely wrinkled and has an intact bloom and intense blue color. Unfortunately, because the 'Black Corinth' vine has very fruitful basal buds and a significant fraction of the fruit is not borne on the fruiting canes, cane severing initiates the drying process for only a portion of the crop. Subsequent shake harvesting yields a mixture of fresh and dried fruit, a combination that is difficult to handle and is susceptible to mold. Earl Rocca solves this problem by finish-drying the shake-harvested fruit on a continuous

Figure 32.7 'Thompson Seedless' on severed canes after 6 weeks of drying on the vine. *Photo: Henry E. Studer.*

paper tray after several weeks of vine drying. However, juice from the fresh berries damaged during shake-harvesting diminishes the blue color of the vine-dried fruit. Hence, the full potential for improved raisin quality is not realized with this modified harvesting system. Hiyama Farms near Fowler, California circumvents the problem of fresh fruit in the vine head region by hand-harvesting and tray-drying all of the fruit borne behind the cut canes before machine-harvesting the vine-dried fruit. While these two harvesting methods are commercially viable, the ideal of a one-pass "from-vine-to-bin" raisin harvest remains to be accomplished.

Sprays of calcium carbonate and ethyl oleate applied to cane-severed vines cause an increase in the fruit drying rate. This technique was pioneered in Australia, and has since been tested extensively by Vincent Petrucci of California State University at Fresno. The coloration of the dried fruit is lighter and more varied. At harvest the dried fruit is shaken and collected directly into bulk bins. Although 'Thompson Seedless' vines have relatively unfruitful basal buds, some fruit is borne in the vine head behind the cane cut point. This fruit must be hand harvested and hung to dry in order to avoid problems during shake harvest. The chemicals used to promote drying also appear to further depress vine productivity. The added cost of the chemicals and their application, coupled with the lack of a strong consumer demand for this type of raisin, has further discouraged widespread adoption of this production system in California.

'Thompson Seedless' grapes, if cane-cut at maturity, do not completely and consistently dry to raisins on the vine in the Fresno area. They do dry completely in the desert areas of Arizona and in the Coachella Valley of California. Canes cut at fruit maturity in early July of 1985 at Thermal, California, dried to well below 14 percent moisture on the vine by September 1. In the Bakersfield area fruit maturity is earlier than at Fresno, and the mean temperature is higher in the months of

Figure 32.8 Green berries are still present on these shaded 'Thompson Seedless' clusters even after 8 weeks of drying on the vine. *Photo: Henry E. Studer.*

Figure 32.9 Machine harvest of DOV 'Zante Currant' raisins on the Glen Wilkins ranch, using an Up-Right Harvesters machine. *Photo: Henry E. Studer.*

August, September, and October. Although there tends to be more frequent rain south of Fresno, that should not affect DOV fruit seriously since it dries out rapidly after a rain. Because fruit there would tend to dry more completely on the vine, regions south of Fresno may offer some advantages for 'Thompson Seedless' DOV production.

MECHANIZING THE CANE SEVERING OPERATION

For raisin harvest based on cane severing, only the actual severing of the canes remains a manual labor operation. Many trellising schemes have been devised in efforts to address this problem. The approach is basically the same for each one: train the vine so that the fruit-bearing canes are physically segregated from the replacement fruiting canes. This should allow a cutting device passing alongside the vine to nonselectively sever the fruiting canes without destroying the renewal wood. In addition, final pruning of the vine in winter would then be much simpler and faster, reduced in essence to a cleanup operation.

The Alternating Duplex training system, with either wrapped or draped canes, was developed as one attempt at this goal. Fruit production alternated with cane production on each side of the trellis from year to year. The design was based on head training and the use of a moveable foliage wire to force the replacement shoots to one side of the vine. The results of simulated mechanical cane severing showed that the number of good canes available after cane severing was significantly increased by use of the moveable wire. However, selective manual cane cutting was still superior in this regard. Moreover, the studies again demonstrated how hard it is to confine the fruit to the harvest zone, even for 'Thompson Seedless' vines, which have relatively unfruitful basal buds (Figure 32.10).

Figure 32.10 Alternating Duplex trained vine. Clusters on the right are in the fruiting cane replacement zone and will not be affected when the fruiting canes on the left are severed. The presence of this fruit complicates the harvest operation. *Photo: Henry E. Studer.*

NATURAL DRIED-ON-THE-VINE RAISIN PRODUCTION (NDOV)

With very early maturity and the right drying conditions, grapes will naturally dry on the vine (NDOV) without having their canes severed. This occurs, for example, with the 'Thompson Seedless,' 'Perlette,' and 'Flame Seedless' varieties in the Coachella Valley during the hot months of summer and early fall. This was also observed with certain of Harold Olmo's early table grape selections grown in the 1970s at the Kearney Agricultural Center as cordon-trained, spur-pruned vines (Figure 32.11). The drying process commenced naturally without cane pruning as a necessary precondition. These observations suggest the possibility that NDOV raisins can be produced on spur-pruned vines that might permit both mechanical harvesting and mechanical winter pruning.

This would represent a real breakthrough in lowering production costs and labor requirements. However, the raisins of some varieties (e.g., 'Flame Seedless') are susceptible to shatter if produced naturally rather than by cane severing. Moreover, and maybe most important, cane severing initiates the drying process, and the grower can control the timing of this operation rather than rely on vine physiology, which may be influenced by weather and other factors. Cane severing is a very powerful management tool for the grower.

Figure 32.11 In the future, early maturing grape varieties that dry naturally on the vine may permit mechanized vine pruning as well as machine harvesting without severing the canes. *Photo: Henry E. Studer.*

At present, practical alternatives to hand-harvested, sun-dried 'Thompson Seedless' raisin production include shake harvesting from severed canes onto continuous trays (with the obvious disadvantages posed by inclement weather) and shake harvesting of partial DOV fruit with artificial dehydration or sun drying as a finishing operation. In the latter case, fruit production from shoots behind the point where the canes are severed continues to pose a serious problem, both for 'Thompson Seedless' and for 'Black Corinth' varieties. A practical, long-term solution to this problem that is not detrimental to yield would greatly enhance the economic viability of DOV culture and would be of immense benefit to the raisin industry.

REFERENCES

Christensen, P., C. Lynn, H. P. Olmo, and H. E. Studer. 1970. Mechanical harvesting of 'Black Corinth' raisins. Calif. Agric. 24(10):4–6.

Christensen, P., and H. E. Studer. 1982. Long-term response of 'Thompson Seedless' to three raisin harvest methods: Hand harvest; machine harvest, continuous tray; and dried-on-the-vine, machine harvest. In Proceedings of the grape and wine centennial symposium, 1980. Davis: University of California, Davis, Department of Viticulture and Enology.

Studer, H. E. 1984. The Alternating Duplex: A vine training system for mechanized raisin production. Transactions of the ASAE 27(4):986–89.

Studer, H. E. 1985. Raisin production by natural on the vine drying. ASAE paper number 85–1566, presented at the Winter meeting of the American Society of Agricultural Engineers, Chicago, IL.

Studer, H. E. 1988. Vine drying: An arid region raisin production system. ASAE paper number 88–1572, presented at the Winter meeting of the American Society of Agricultural Engineers, Chicago, IL.

Studer, H. E. 1992. Implications of vine drying for the raisin industry. ASAE paper number 92–8506, presented at the Winter meeting of the American Society of Agricultural Engineers, Nashville, TN.

Studer, H. E., and M. Kliewer. 1988. Mechanical vine pruning in California. In Proceedings of the 2nd International Seminar on Mechanical Pruning of Vineyards. February 15–20, Villa Rietti Rota, Villanova di Motta di Livenza, Treviso, Italy. 24–30.

Studer, H. E., and H. P. Olmo. 1968. Mechanically harvesting the 'Thompson Seedless' grape. Agric. Eng. 49(2):76–81.

Studer, H. E., and H. P. Olmo. 1971. The severed cane technique and its application to mechanical harvesting of raisin grapes. Trans. ASAE 14(1):38–43.

Studer, H. E., and H. P. Olmo. 1973. Vine-drying of 'Thompson Seedless' grapes. Trans. ASAE 16(5):944–48, 952.

Studer, H. E., and H. P. Olmo. 1974. Parameters affecting the quality of machine harvested raisins. Trans. ASAE 17(4):783–86, 792.

Studer, H. E., and H. P. Olmo. 1974. Raisin pickup from a continuous paper tray. Trans. ASAE 17(1):20–23.

Studer, H. E., H. P. Olmo, and E. Rocca. 1973. Mechanical harvesting of raisin grapes . . . An evaluation of methods for severing fruiting canes. Calif. Agric. 27(3):10–12.

Winkler, A. J., and L. H. Lamouria. 1956. Machine harvesting of grapes. Calif. Agric. 10(5):9, 14.